SUBCATEGORIES AND MACT FLOOR DETERMINATIONS FOR EXISTING STATIONARY RECIPROCATING INTERNAL COMBUSTION ENGINES (RICE)

Presented by:
The Reciprocating Internal Combustion Engine Work Group
Of the Industrial Combustion Coordinated Rulemaking

Presented to:
The Coordinating Committee
Of the Industrial Combustion Coordinated Rulemaking

August 12, 1998

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The RICE Work Group has determined subcategories and MACT floors for existing RICE and has documented the rationale that led to the Group's determinations. The Work Group recommends that the Coordinating Committee forward these determinations and associated rationale to EPA.

RICE Subcategories

The Reciprocating Internal Combustion Engine (RICE) Work Group has determined that the following ten subcategories should be established for existing RICE for the purpose of MACT floor:

Spark-Ignition, Natural Gas 4-Stroke Rich Burn Engines
Spark-Ignition, Natural Gas 4-Stroke Lean Burn Engines
Spark-Ignition, Natural Gas 2-Stroke Lean Burn Engines
Spark-Ignition, Digester Gas and Landfill Gas Engines
Spark-Ignition, Propane, Liquid Petroleum Gas (LPG), and Process Gas Engines
Spark-Ignition, Gasoline Engines
Compression-Ignition, Liquid Fuel Engines (diesel, residual/crude oil, kerosene/naphtha)
Compression-Ignition, Dual Fuel Engines
Emergency Power Units
Small Engines (200 brake horsepower or less)

The Work Group determined that these ten subcategories are necessary for MACT floor to fully capture significant technical and operational differences among existing RICE.

The RICE Work Group recommends that the Coordinating Committee forward to EPA these subcategories for existing RICE. The RICE Work Group recognizes that the final subcategories for any MACT standards established for existing RICE may be different than those established for the purposes of MACT floor to incorporate additional information that is gained in developing the final MACT standards.

MACT Floors for Existing RICE

The RICE Work Group has reached consensus on MACT floors for existing RICE, by subcategory. The RICE Work Group has determined that the MACT floor for Spark-Ignition, Natural Gas 4-Stroke Rich Burn Engines is non-selective catalytic reduction (NSCR) based on the ICCR Population Database. For all other subcategories of existing RICE, the Work Group has determined that there is no MACT floor. The RICE Work Group achieved consensus on

these determinations in accordance with the provisions for MACT floor, as the minimum acceptable level of emission control for MACT, provided in Section 112(d) of the Clean Air Act, as amended in 1990. The MACT floors are listed below by subcategory.

MACT Floors

RICE Subcategory	MACT Floor
Spark-Ignition, Natural Gas 4-Stroke Rich Burn Engines	Non-Selective Catalytic Reduction
Spark-Ignition, Natural Gas 4-Stroke Lean Burn Engines	No MACT Floor
Spark-Ignition, Natural Gas 2-Stroke Lean Burn Engines	No MACT Floor
Spark-Ignition, Digester Gas and Landfill Gas Engines	No MACT Floor
Spark-Ignition, Propane, LPG, and Process Gas Engines	No MACT Floor
Spark-Ignition, Gasoline Engines	No MACT Floor
Compression-Ignition, Liquid-Fuel Engines (diesel, residual/crude oil, kerosene/naphtha)	No MACT Floor
Compression-Ignition, Dual Fuel Engines	No MACT Floor
Emergency Power Units	No MACT Floor
Small Engines (200 brake horsepower or less)	No MACT Floor

The RICE Work Group recommends that the Coordinating Committee forward these MACT floor determinations for existing RICE to EPA. The RICE Work Group acknowledges that final requirements in any MACT standards for existing RICE may include requirements that go beyond the MACT floor determinations. The RICE Work Group continues to evaluate above-the-floor MACT options, including emission reduction devices and good combustion practices.

Rationale for RICE Subcategories

Existing stationary RICE come in a variety of makes, models, and sizes. The RICE Work Group established ten subcategories for existing RICE to distinguish between different classes of engines. The ten subcategories incorporate the following factors:

fuel type,
engine design characteristics,
emergency power use, and
small engine size (200 brake horsepower or less).

Fuel type was used as the basis for subcategorization to incorporate the following factors:

1. Stationary RICE use a variety of liquid and/or gaseous fuels.
2. Fuels, in general, are not interchangeable for stationary RICE, as engine design and operating characteristics vary depending on fuel type. For example, certain fuels are ignited in the internal combustion process by means of compression (compression ignition, or CI), while other fuels are ignited by means of an

electrical spark (spark ignition, or SI).

3. Fuel composition and associated mixing affect initiation, rate and completeness of combustion, which, in turn, may influence HAPs formation and emissions.
4. Fuel type also can affect the viability of control options to reduce HAP emissions from RICE, as some fuels, such as landfill gas and digester gas, tend to foul catalytic controls and render them ineffective. Also, some oxidation catalysts may be unsuitable for liquid fuel CI engines depending on the sulfur content of the fuel.

Engine design characteristics, including ignition system (compression ignition or spark ignition), air scavenging cycle (4-stroke or 2-stroke), and air-to-fuel ratio (rich burn or lean burn), were used as the basis for subcategorization to incorporate the following factors:

1. Ignition systems and air scavenging cycles are design characteristics and are not interchangeable for existing RICE. Also, operation in rich or lean burn mode is principally fixed by engine design.
2. Engine design characteristics affect the combustion process, including factors that may influence HAPs formation, such as fuel and air mixing, ignition, flame propagation, and quenching.
3. Engine design characteristics also can affect the viability of control options to reduce HAP emissions from RICE by affecting the constituents in the RICE exhaust stream and the exhaust temperature.

A subcategory for emergency power units was included in the RICE subcategories to incorporate the following factors:

1. Emergency power units are used during emergencies. For example, 1) when electric power from the local utility is interrupted or becomes unreliable and 2) to pump water in the case of fire or flood. The duration of the emergencies is entirely beyond the control of the source, and, when they do occur (except in the case of a major catastrophe) rarely last more than a few hours, often only a few minutes.
2. Emissions from these units are expected to be low on an annual basis; emissions occur only during emergency situations or for a very short time to perform maintenance checks and operator training. State and local regulators generally have not required emission controls for emergency power units.
3. Emergency power units operate for very few hours per year. EPA previously determined that 500 hours is an appropriate default assumption for estimating the number of hours that an emergency power unit could be expected to operate under worst-case conditions. In reality, most emergency power units operate for less than 500 hours, some as little as 50 hours or less per year.
4. Add-on catalytic control devices that are most applicable to reduce HAPs from RICE would be less effective on an annual basis for emergency power units, since emergency power units generally operate for brief periods (only a few minutes or

hours). Therefore, a greater percentage of the emergency power units' operation, as compared to operation of peaking or baseload engines, will occur during catalyst warm-up, when the catalyst's effectiveness will be lower. The RICE Test Plan will provide more information about catalyst warm-up.

Small engine size was used as the basis for subcategorization to incorporate the following factors:

1. Although stationary RICE range in size from 50 brake horsepower (bhp) to 11,000 bhp, engines 200 brake horsepower or less generally have different utilization than larger engines. In most cases, engines 200 brake horsepower or less are nonroad sources (as defined in 40 CFR Part 89.2), not stationary sources. Small stationary units are more likely to be used for oil/gas field production or irrigation, while large stationary units are more likely to be used in electric power generation, gas transmission and gas processing.
2. Small stationary engines (other than emergency power units) generally are not located at facilities that are major sources of HAP emissions.
3. HAP emissions from a small unit are expected to be low on an annual basis and state and local air regulatory authorities generally have not required emission controls for small stationary engines, which are less cost-effective to regulate.

Rationale for RICE MACT Floor Determinations

The RICE Work Group determined the MACT floors for existing RICE by subcategory, in accordance with the provisions for MACT included in Section 112(d) of the Clean Air Act, as amended in 1990. In order to identify the best performing group of sources and determine the MACT floors, the RICE Work Group reviewed the following available information related to HAPs emissions from existing RICE:

existing add-on controls that may reduce HAPs,
existing good combustion practices that may reduce HAPs, and
existing emissions data, air regulations, and air permit limitations for HAPs.

The RICE Work Group assessed the prevalence of existing, add-on controls by reviewing information available in the ICCR Population Database for RICE. No existing control techniques are in place specifically to address the formation or reduction of HAPs from existing RICE. The RICE Work Group came to consensus that, among existing add-on controls, controls that involve oxidation are the most likely to reduce HAPs from RICE. For Spark Ignition, Natural Gas, 4-Stroke Rich Burn Engines, the RICE Work Group determined that the average of the best performing 12 percent of engines in the ICCR Population Database for that subcategory have non-selective catalytic reduction (NSCR) controls. NSCR is a catalytic post-combustion control device that incorporates oxidation and, based on the RICE Work Group's engineering judgement, is likely to oxidize HAP emissions, such as formaldehyde, from spark ignition natural gas-fired 4-stroke rich burn engines. Therefore, in accordance with the Clean Air Act provisions, the RICE Work Group determined that NSCR is the MACT floor for Spark Ignition, Natural Gas, 4-Stroke Rich Burn Engines. The RICE Work Group reviewed the possibility of establishing HAP emission limitations or emission reduction targets as MACT floor for the Spark Ignition Natural Gas 4-Stroke Rich Burn subcategory. However, emissions data available in the ICCR Emissions Database at present are insufficient to allow the Work Group to set appropriate HAP emission limitations or HAP emission reduction targets for SI natural gas 4-stroke rich burn units using NSCR. For all other subcategories, the RICE Work Group determined that there are insufficient numbers of add-on controls that may reduce HAPs in the ICCR Population Database to use add-on controls as the basis for MACT floor. Therefore, the RICE Work Group determined that no add-on control is the MACT floor control type for those subcategories.

The RICE Work Group assessed existing good combustion practices by using information available in the ICCR Population Database, information from state air permitting authorities and the expertise of Work Group members. Practices that maintain good engine performance may lead to more complete combustion and, therefore, may decrease the likelihood of increased HAP emissions that may be associated with incomplete combustion or engine failure. However, at this time, the Work Group has not identified any emissions data to link improved maintenance and operating practices to reduced HAP emissions. Existing regulatory requirements for inspection and maintenance practices were identified for only a few sources in two states: Louisiana and California. In both cases, the source owners and operators established inspection and maintenance plans that are site-specific and the content of the plans was negotiated with the air permitting authorities. Based on a review of all available information, the RICE Work Group was unable to identify specific practices that should be included in the MACT floor for existing RICE.

The Work Group assessed emissions information by reviewing available emissions test data for HAPs, state air regulations for RICE, and air permit limits. The Work Group concluded that the available emissions test data are insufficient to be used as the basis for MACT floor. The existing data varied widely and often lacked information about the status of the RICE tested, including key engineering and operating data. These factors precluded the Work Group from determining whether any specific emission levels reported would be achievable for existing RICE. The Work Group confirmed that there are no state air emission regulations for HAP emissions from RICE units. In addition, the Work Group reviewed state air permit limitations for HAPs and concluded that the few HAP emission limitations identified should not be used as the basis for MACT floor since limits could not be subcategorized and the RICE Work Group was unable to determine whether the limits would be achievable based on the available information. Therefore, the Work Group determined that presently there is insufficient information to establish HAP emission limitations or HAP emission reduction targets as a part of the MACT floors for existing RICE. Given the critical emissions data gaps, the RICE Work Group agreed, by consensus, that additional emissions data are needed to support the MACT rule development. The test plan developed by the RICE Work Group and recommended to EPA by the Coordinating Committee will be conducted at Colorado State University and will provide the Work Group with additional emissions data.

SUBCATEGORIES AND MACT FLOOR DETERMINATIONS FOR EXISTING STATIONARY RECIPROCATING INTERNAL COMBUSTION ENGINES (RICE)

The purpose of this document is threefold:

1. Provide the Reciprocating Internal Combustion Engine (RICE) Work Group's determinations for subcategories and MACT floors for existing RICE to the Coordinating Committee of the Industrial Combustion Coordinated Rulemaking (ICCR);
2. Document the rationale that led to the development of the RICE subcategories and MACT floors for existing RICE; and
3. Recommend that the Committee forward the subcategories, MACT floors and rationale to EPA.

Section 1.0 presents the Work Group's determinations regarding subcategories for existing RICE and the rationale supporting those subcategories. **Section 2.0** presents the Work Group's MACT floor determination for each subcategory, along with the supporting rationale for the MACT floor findings.

1.0 SUBCATEGORIES FOR EXISTING RICE

Existing stationary RICE come in a variety of makes, models, and sizes and use a variety of liquid and gaseous fuels. In order to distinguish between different classes of engines, the RICE Work Group established ten subcategories of existing RICE for the purpose of MACT floor. The RICE Work Group determined that these ten subcategories are the minimum number necessary for MACT floor to fully capture significant technical and operational differences among existing RICE. The RICE subcategories are listed below:

Spark-Ignition, Natural Gas 4-Stroke Rich Burn Engines
Spark-Ignition, Natural Gas 4-Stroke Lean Burn Engines
Spark-Ignition, Natural Gas 2-Stroke Lean Burn Engines
Spark-Ignition, Digester Gas and Landfill Gas Engines
Spark-Ignition, Propane, Liquid Petroleum Gas (LPG), and Process Gas Engines
Spark-Ignition, Gasoline Engines
Compression-Ignition, Liquid Fuel Engines (diesel, residual/crude oil, kerosene/naphtha)
Compression-Ignition, Dual Fuel Engines
Emergency Power Units
Small Engines (200 brake horsepower or less)

1.1 Reasons for Subcategorization

The RICE Work Group established subcategories for RICE to incorporate factors that may affect the HAP emissions from RICE and/or the viability of control techniques that may reduce HAP emissions from RICE. The Work Group determined that fuel type and engine design characteristics are the key factors that affect HAP emissions and the viability of controls. In addition, the Work Group incorporated subcategories for RICE classified as emergency power units and RICE classified as small engines.

Further discussion of the rationale for subcategorization is provided in the sections below.

1.1.1 Fuel Type

Fuel type was used as the basis for subcategorization to incorporate the following factors:

1. Stationary RICE use a variety of liquid and/or gaseous fuels.
2. Fuels, in general, are not interchangeable for stationary RICE, as engine design and operating characteristics vary depending on fuel type. For example, certain fuels are ignited in the internal combustion process by means of compression (compression ignition, or CI), while other fuels are ignited by means of an electrical spark (spark ignition, or SI).
3. Fuel type, composition and associated mixing affect initiation, rate and completeness of combustion, which, in turn, may influence HAPs formation and HAP emissions.
4. Fuel type also can affect the viability of control options to reduce HAP emissions from RICE, as some fuels, such as landfill gas and digester gas, tend to foul catalytic controls and render them ineffective. Also, some oxidation catalysts may be unsuitable for liquid fuel CI engines depending on the sulfur content of the fuel.

1.1.1.1 Liquid Fuels

The following liquid fuels are used for stationary RICE: diesel, residual/crude oil, kerosene/naphtha (jet fuel), and gasoline. Two subcategories were created for liquid fuels to distinguish between those fuels that are used in CI engines and those fuels that are used in SI engines. There was no further subcategorization for liquid-fueled RICE.

Liquid fuels used in CI engines include distillate oil (Nos. 1-4), residual oil (Nos. 5 and 6), and kerosene/naphtha (jet fuel). Gasoline is the only liquid fuel used in stationary SI engines. With the exception of extremely small co-generation applications ($\approx$<100 kW) gasoline engines are seldom utilized in stationary applications. Most stationary liquid-fueled engines operate using compression ignition. CI engines operate on a wide variety of liquid fuels ranging from light distillates such as No. 1 fuel oil to residuals from the refining process, sometimes called residual or "heavy" fuel, that are virtually solid at room temperature.

1.1.1.2 Gaseous Fuels

The following gaseous fuels are used for stationary RICE: natural gas, digester gas, landfill gas, propane, liquid petroleum gas (LPG), and process gas. Most gaseous fuels are used in SI engines. In CI engines, gaseous fuels may be used as the primary fuel, but a small pilot injection of liquid fuel (usually diesel) is required for ignition. CI engines where liquid fuel is used for ignition and gaseous fuels are used as the primary fuel are commonly called "dual fuel" engines.

Subcategories for gaseous fuels distinguish between CI engines (dual fuel) and SI engines. In addition, gaseous fuels used in SI engines were further subcategorized to reflect the differences in the gaseous fuels, which affect engine design characteristics, and may affect HAP emissions formation and the viability of control devices.

Natural gas was placed in a separate subcategory. For the purposes of this subcategorization, natural gas means a naturally occurring mixture of hydrocarbon and non-hydrocarbon gases found in geologic formations beneath the earth's surface, of which the principal constituent is methane. Natural gas may be either field gas or pipeline quality gas.

Digester and landfill gases were placed in a separate subcategory. These fuels are by-products of wastewater treatment and land application of municipal refuse. These gases, which are formed through anaerobic decomposition of organic materials, are principally comprised of methane (50% - 65%) and carbon dioxide (35% - 50%). Trace quantities of other compounds including hydrogen sulfide, ammonia, volatile organic compounds (VOCs) and particulate matter (PM) also are present. Digester and landfill gases are similar in their composition, and their emissions after combustion are very similar to natural gas. There are, however, some differences in that emissions from digester and landfill gas would contain trace quantities of chlorinated compounds typically not found in natural gas.

Both digester gas and landfill gas contain a family of silicon-based gases collectively called siloxanes. Siloxanes are found in many cosmetics and cleaning solutions that are disposed of in either landfills or sewers. Combustion of siloxanes forms compounds that can foul fuel systems, combustion chambers, and post-combustion catalysts. The fouling renders catalysts inoperable within a very short time period. Because of this problem, catalytic technology has not been demonstrated to work effectively on internal combustion engines burning these fuels. This also includes dual fuel engines that burn diesel and either digester gas or landfill gas. Dual fuel engines are common within the wastewater treatment and landfill industries.

Propane, liquid petroleum gas (LPG), and process gas were placed in a third subcategory. All three are refined gases that largely consist of C_2 through C_4 hydrocarbons in either the alkane or alkene family. These differences in fuel composition may lead to different HAP emissions than those from natural gas.

1.1.2 Engine Design Characteristics

The following engine design characteristics were used as the basis for RICE subcategories:

ignition system (compression ignition or spark ignition)
air scavenging cycle (4-stroke or 2-stroke)
air-to-fuel ratio (rich burn or lean burn)

These design characteristics were used as the basis for subcategorization to incorporate the following factors:

1. Ignition systems and air scavenging cycles are not interchangeable for existing RICE. Also, operation in rich or lean burn mode is principally fixed by engine design.
2. Engine design characteristics affect the combustion process, including factors that may influence HAPs formation, such as fuel and air mixing, ignition, flame propagation, and quenching.
3. Engine design characteristics also can affect the viability of control options to reduce HAP emissions from RICE by affecting the constituents in the RICE exhaust stream and the exhaust temperature.

Descriptions of the ignition systems for RICE, the air scavenging cycles, and air-to-fuel ratios are provided below.

1.1.2.1 Ignition System (CI or SI)

There are two ignition systems for stationary RICE: spark ignition (SI), also known as Otto cycle, and compression ignition (CI) also known as the Diesel cycle. The SI cycle uses lower compression ratios than does the CI cycle and relies on an electrical spark to ignite the fuel mixture in the cylinder. The CI cycle uses high compression ratios and the resultant high temperatures to produce auto-ignition of the fuel in the cylinder. The intake process for both SI and CI cycles, including the fuel mixing process and ignition timing, affects the initiation and the rate of combustion, which, in turn, may influence HAPs formation. A more detailed description of both operating cycles is provided below.

1.1.2.1.1 Spark Ignition (SI)

SI engines utilize a "spark" generated by a spark plug and associated electronics to initiate combustion. Traditionally, one or more of these spark plugs are mounted directly in the combustion chamber. When applied to larger bore engines, such open combustion chamber (OCC) systems result in significant combustion instability and can operate only at moderately lean air-to-fuel ratios. To extend the lean limit (thereby reducing fuel usage and reducing NO_x emissions) engine manufacturers introduced two-stage combustion. In the first stage, the spark ignites a small quantity of fuel in a rich air-to-fuel mixture in a separate chamber, which is known as a pre-combustion chamber (PCC). Then, in the second stage, the bulk of the fuel, which is in a very lean air-to-fuel mixture, is ignited by the hot, burning gases jetting from the PCC. Recently several after-market manufacturers have offered alternative electrical based ignition systems such as plasma jets. Typically these high-energy ignition systems operate in an OCC.

1.1.2.1.2 Compression Ignition (CI)

Compression ignition engines operate at significantly higher compression ratios than SI engines, with the resultant heat of compression raising the temperature of the trapped air or air and fuel charge to ≈800°F or more. Fuel (usually liquid) injected into this hot compressed gas then spontaneously vaporizes, disassociates and ignites. Often CI engines are referred to as "diesel" engines after the originator and patent holder of the method, Rudolph Diesel. While some diesel engines utilize a pre-combustion chamber to assist in ignition, particularly at part load, most large stationary CI diesels have OCCs to maximize efficiency and performance.

Dual fuel CI engines scavenge or inject gaseous fuels into the combustion chamber with the fresh air charge and then utilize a small "pilot injection" of liquid fuel (usually No. 2 diesel) to ignite the mixture. The less expensive gaseous fuel usually provides 90-99% of the input energy while the more expensive liquid fuel provides the balance. Originally, dual fuel engines were simple conversions of OCC diesel engines which maintained the ability to operate on "full diesel" (i.e. 100% liquid fuel). While offering favorable NO_x emissions in this configuration, subsequent regulations to further reduce NO_x emissions resulted in several engine manufacturers offering such engines fitted with PCCs to reduce the pilot fraction to ≈1% or less.

1.1.2.2 Air Scavenging Cycles (2-stroke or 4-stroke)

Reciprocating internal combustion engines utilize either 2-stroke cycle (2SC) or 4-stroke cycle (4SC) scavenging. Two-stroke engines complete the power cycle in a single crankshaft revolution as compared to the two crankshaft revolutions required for 4-stroke engines. The scavenging cycle impacts the trapped air and fuel charge and mixing, which may impact HAPs formation. A description of the scavenging cycles is provided below.

1.1.2.2.1 4-Stroke Cycle (4SC)

4SC engines are the most familiar engine type due to their use in vehicular applications. A 4SC engine undergoes four distinct events or strokes: intake, compression, power and exhaust. 4SC engines may be either naturally aspirated (NA) or turbocharged (TC). A 4SC NA engine uses the suction from the intake stroke to entrain the air charge and uses the exhaust stroke to remove exhaust gases from the cylinder. Inasmuch as maximum power delivery is limited by the air supply, 4SC NA engines tend to operate near or slightly rich of stoichiometry, the theoretical air-to-fuel ratio required for complete combustion, and are commonly called rich-burn engines. In general, financial and performance considerations require that large stationary 4SC engines operate at specific outputs two to four times that obtainable with NA alone. These large 4SC engines use an auxiliary air compressor to increase the charge density at the engine intake. The most common method is to use an exhaust-driven turbine, called a turbocharger. Turbocharged units produce a higher power output for a given engine displacement. In order to maximize the fresh air charge density, most 4SC turbocharged (4SC TC) engines utilize an aftercooler or intercooler to remove the heat of compression from the fresh air charge. Typically, mechanical and/or thermal loading limits the output of 4SC TC engines. 4SC TC gaseous-fueled engines that are spark-ignited can operate from rich of stoichiometric to more than twice as lean as stoichiometric (over 100% excess combustion air).

1.1.2.2.2 2-Stroke Cycle (2SC)

To maximize power output/density, 2SC engines combine the intake and compression operations into one stroke and the power and exhaust operations into a second stroke. Consequently, an auxiliary device is required to "scavenge" the engine. In their simplest form this may consist of pumping off the underside of the piston or the addition of one or more scavenging pump cylinders to the same crankshaft connecting the power cylinders. In more sophisticated applications gear or motor driven blowers may supply scavenging air. Typically, due to inherent limitations in 2SC scavenging, these pump scavenged (2SC PS) or blower scavenged (2SC BS) 2SC engines operate somewhat lean of stoichiometric and are also classified as "lean burn".

Like 4SC, financial and performance considerations (in particular the load of crank driven pumps/blowers), require that larger more modern stationary 2SC engines utilize turbochargers (2SC TC) and intercoolers to increase charge air density and specific output. 2SC TC engines typically operate lean of stoichiometric conditions and are known as lean burn engines.

1.1.2.3 Air-to-Fuel Ratio ("rich" or "lean")

Stationary RICE operate with various air-to-fuel ratios. In general, air-to-fuel ratios may be classified as either rich or lean of stoichiometry, the theoretical air-to-fuel ratio required for complete combustion. All stationary CI engines are lean burn engines, usually utilizing turbochargers and intercoolers to achieve the desired fresh air density. SI engines may be either rich-burn engines or lean burn engines.

A common method used to differentiate between “rich burn” and “lean burn” engines is the percentage oxygen in the exhaust stream. Several regulatory agencies have adopted a value of 4% oxygen in the exhaust as the defining limit for “rich burn” engines. An engine with more than 4% exhaust oxygen is classified as “lean burn”. In point of fact, most “lean burn” engines manufactured today have at least 7% exhaust oxygen.

1.1.3 Emergency Power Units

Emergency power units are defined as stationary RICE that operate as mechanical or electrical power sources during emergencies, or for scheduled maintenance checks or operator training. For example, 1) when electric power from the local utility is interrupted or becomes unreliable and 2) to pump water in the case of fire or flood. The emission source is typically a gasoline or diesel-fired engine but may be a gaseous-fueled engine. This subcategory would not include 1) peaking units at electric utilities; 2) engines at industrial facilities that typically operate at low rates, but are not confined to emergency purposes; and 3) any standby generator that is used during time periods when power is reliably available from the utility.

A subcategory for emergency power units was included in the RICE subcategories to incorporate the following factors:

1. Emergency power units are used during emergency. For example, 1) when electric power from the local utility is interrupted or becomes unreliable and 2) to pump water in the case of fire or flood. The duration of the emergencies is entirely beyond the control of the source, and, when they do occur (except in the case of a major catastrophe) rarely last more than a few hours, often only a few minutes.
2. Emissions from these units are expected to be low on an annual basis; emissions occur only during emergency situations or for a very short time to perform maintenance checks and operator training. State and local regulators generally have not required emission controls for emergency power units.
3. Emergency power units operate for very few hours per year. EPA previously determined that 500 hours is an appropriate default assumption for estimating the number of hours that an emergency power unit could be expected to operate under worst-case conditions. (Memorandum on Calculating Potential to Emit (PTE) for Emergency Generators from John S. Seitz, Director of the Office of Air Quality Planning and Standards, September 6, 1995.) In reality, most emergency power units operate for less than 500 hours, some as little as 50 hours or less per year.
4. Add-on catalytic control devices that are most applicable to reduce HAPs from RICE would be less effective on an annual basis for emergency power units, since emergency power units generally operate for brief periods (only a few minutes or hours). Therefore, a greater percentage of the emergency power units' operation, as compared to operation of peaking or baseload engines, will occur during catalyst warm-up, when the catalyst's effectiveness will be lower. The RICE Test Plan will provide more information about catalyst warm-up.

1.1.4 Small Engines

Stationary RICE range in size from 50 brake horsepower (bhp) to 11,000 bhp. A separate subcategory for small engines (200 bhp or less) was created to incorporate the following factors:

1. Engines 200 brake horsepower or less generally have different utilization than larger engines. In most cases, engines 200 brake horsepower or less are nonroad sources (as defined in 40 CFR Part 89.2), not stationary sources. Small stationary units are more likely to be used for oil/gas field production or irrigation, while large stationary units are more likely to be used in electric power generation, gas transmission, and gas processing.

2. Small stationary engines (other than emergency power units) generally are not located at facilities that are major sources of HAP emissions.
3. HAP emissions from a small unit are expected to be low on an annual basis and state and local air regulatory authorities generally have not required emission controls for small stationary engines, which are less cost-effective to regulate. For example, the State of Texas only requires that stationary engines rated at 250 bhp or greater be registered with the state air regulatory agency.

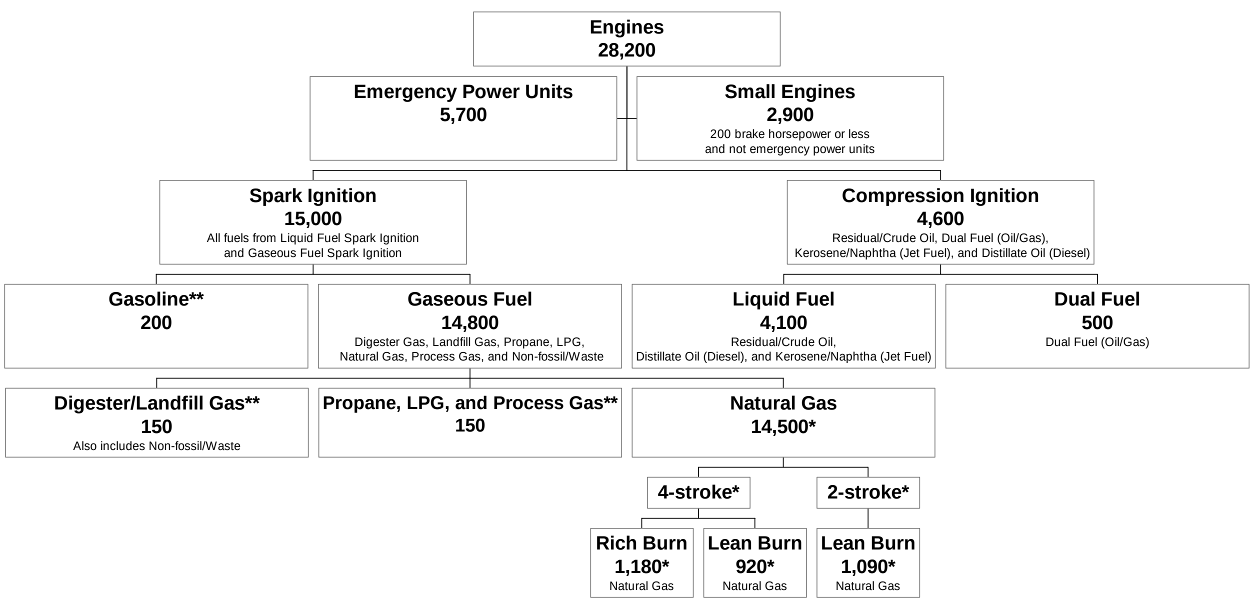
1.2 Engines in the ICCR Population Database by Subcategory

The following diagram provides the total number of RICE included in the ICCR Population Database Version 2 and the distribution of these units within each assigned subcategory. The RICE Work Group reached consensus on using version 2 of the ICCR Population Database instead of version 3 due to the following reasons:

1. The additional units under version 3 do not affect the determined MACT Floor(s).
2. Information for the additional units does not include specific parameters, such as engine make and model, which are necessary for subcategorization.
3. The RICE Work Group conducted considerable efforts in refining the gathered data in version 2.

The RICE distribution in the Population Database by subcategory is presented below.

EPA Population Database Subcategorization Chart



*3,190 natural gas-fired engines contain enough information to be further subcategorization

**Further subcategorization not necessary for MACT floor determination.

2.0 APPROACH AND RATIONALE FOR MACT FLOORS

The RICE Work Group determined the MACT floors for existing RICE, by subcategory, in accordance with the provisions for MACT included in Section 112(d) of the Clean Air Act, as amended in 1990. In order to identify the best performing group of sources and determine the MACT floors, the RICE Work Group reviewed the following available information related to HAPs emissions from existing RICE:

existing add-on controls that may reduce HAPs,
existing good combustion practices that may reduce HAPs, and
existing emissions, air regulations, and air permit limitations for HAPs.

The MACT floors are listed by subcategory below.

MACT Floors

RICE Subcategory	MACT Floor
Spark-Ignition, Natural Gas 4-Stroke Rich Burn Engines	Non-Selective Catalytic Reduction
Spark-Ignition, Natural Gas 4-Stroke Lean Burn Engines	No MACT Floor
Spark-Ignition, Natural Gas 2-Stroke Lean Burn Engines	No MACT Floor
Spark-Ignition, Digester Gas and Landfill Gas Engines	No MACT Floor
Spark-Ignition, Propane, LPG, and Process Gas Engines	No MACT Floor
Spark-Ignition, Gasoline Engines	No MACT Floor
Compression-Ignition, Liquid-Fuel Engines (diesel, residual/crude oil, kerosene/naphtha)	No MACT Floor
Compression-Ignition, Dual Fuel Engines	No MACT Floor
Emergency Power Units	No MACT Floor
Small Engines (200 brake horsepower or less)	No MACT Floor

2.1 Available Information

Inventory information and emissions source test reports in the ICCR Population and Emissions Databases were used as the primary basis for the MACT floor determinations. State regulations, state air permits, work group expertise, and information from equipment manufacturers and state air regulatory representatives also were considered in determining the MACT floors.

2.1.1 ICCR Population Database

The ICCR Population Database was used for information about existing engines, including information about the prevalence of emission controls. For RICE, the ICCR Population Database currently has inventory information on approximately 28,000 RICE, of which 5,700, or 20% of the entries, are emergency power units. The RICE Work Group came to consensus that the ICCR Population Database was adequate to assist the Group in drawing conclusions about the MACT floor for existing RICE, based on the following:

1. Engines for all known fuels are included in the database.
2. Engines are included for key user segments (SIC codes) that may have facilities that are major sources of HAP emissions.
3. Small and large engines are included in the database.
4. Engines used for emergency power, peaking, and base loads are included in the database.
5. The database provides information on control techniques for existing engines. The RICE Work Group was able to review these techniques to determine which ones may reduce HAPs.
6. The conclusions drawn from the database regarding the prevalence of existing control techniques are consistent with Work Group members' experiences with existing engines and experiences of state air permitting authorities and equipment manufacturers.

Emergency power units were identified in the ICCR Population Database by examining information provided in the "Combustor Description" field and information in the "Hours of Operation" field. If the total number of hours of operation was 500 or less, the engine was considered an emergency power unit. Also, if the “Combustor Description” field included the word “emergency,” the engine was considered an emergency power unit.
The Work Group's findings on control techniques included in the ICCR Population Database are presented in **Section 2.2.1** of this report.

2.1.2 ICCR Emissions Database

The ICCR Emissions Database for RICE includes over 30 air emissions test reports for HAPs. Engines in the ICCR Emissions Database range in size from 39 to 5,500 brake horsepower, so small and large engines have been captured. The test reports represent applications in industrial, pipeline, and utility sectors. The majority of the source tests were conducted in the State of California as part of the AB2588 (Air Toxics "Hot Spots" Information Assessment Act of 1987) program. The State of California is the only state with regulatory requirements for estimating air toxic emissions from RICE. Other emissions data collected by the Gas Research Institute for natural gas-fired engines have been considered in the MACT floor evaluation as well.

The Work Group's findings on HAP emissions data included in the ICCR Emissions Database are presented in **Section 2.2.5** of this report.

2.1.3 State Air Regulations and Air Permit Limits for HAPs

For the purpose of MACT floor, the RICE Work Group limited its review of state air regulations and air permit limits to HAPs only. Although some states regulate air emissions of volatile organic compounds (VOCs) from existing RICE, and some HAPs are VOCs, the relationship between VOC and HAP emissions from existing RICE is unknown. Therefore, the RICE Work Group concluded that VOC emission limitations are insufficient, at this time, to be used as the basis for HAP emission limitations.

Available information on state air regulations and air permit limits for HAPs was obtained from the following sources:

Unified Air Toxics Website (UATW),
RACT/BACT/LAER Databases, and
permit limit information in the ICCR Population Database for RICE.

The information was verified by contacting several states, including Alaska, California, Louisiana, North Carolina, and Texas.

The Work Group's findings on state air regulations for HAPs are presented in **Section 2.2.3** of this report. The findings on air permit limitations for HAPs are presented in **Section 2.2.4** of this report.

2.1.3.1 Unified Air Toxics Website (UATW)

The Unified Air Toxics Website (UATW) was designed as the USEPA's "one stop" site for all information regarding HAPs emissions. The UATW is available on the EPA TTNWEB at http://www.epa.gov/ttn/uatw. The UATW includes HAPs permits and regulations for most state and local agencies. The UATW is an evolving site jointly designed by the EPA Office of Air Quality Planning and Standards (OAQPS), the State and Territorial Air Pollution Program Administrators (STAPPA), and the Association of Local Air Pollution Control Officials (ALAPCO).

The UATW was searched for state and local agencies known to have stringent regulation requirements for toxic emissions, including California, Florida, Louisiana, New Hampshire, North Carolina, Pennsylvania, South Coast AQMD, and Texas. The UATW was also searched using the following keywords: formaldehyde, engine, state, permit, and regulation. In addition, the UATW was searched for state air permit limitations for RICE.

2.1.3.2 RACT/BACT/LAER Databases

The RACT/BACT/LAER Clearinghouse contains information from air permits submitted by most of the state and local air pollution control programs in the United States. The database is available on-line at the TTN web site of the EPA:

http://www.epa.gov/ttn/catc in the CATC (Clean Air Technology) technical site

Emissions limits for RICE were searched by downloading all available databases (historical, transient, and current) of the RACT/BACT/LAER Clearinghouse. Several tables are included in each database; however, only two tables were determined to be relevant to the emission limits search: the Master Table (BLMSTR) and the Notes Table (BLNOTES). BLMSTR contains general information about facilities and their emission permits. BLNOTES provides comments and other additional information about the permits.

The historical, transient, and current RACT/BACT/LAER databases were searched individually for state air permit limitations for RICE.

2.1.3.3 Permit Limit Information in the ICCR Population Database

Version 3 of the ICCR Population Database includes HAPs air permit limits for 49 engines, out of 28,000 engines total. The engines with HAP air permit limits are located at facilities in Louisiana and California. There are 15 facilities with HAP permit limits -- 14 are in Louisiana, and one is in California. HAP permit limits for these engines are reported for at least one of the following pollutants:

xylenes	toluene
naphthalene	n-hexane
formaldehyde	ethylbenzene
chlorine	benzene
aldehydes	

2.2 Rationale for MACT Floor Determinations

2.2.1 Existing Emission Control Techniques

The RICE Work Group assessed existing emission control techniques by 1) determining which control techniques are most likely to reduce HAPs and 2) reviewing information available in the ICCR Population Database to determine the prevalence of those controls for existing RICE.

Based on the information presented below, the RICE Work Group determined that non-selective catalytic reduction (NSCR) should be the MACT floor control type for one subcategory of existing RICE -- Spark Ignition, Natural Gas, 4-Stroke Rich Burn Engines. For all other subcategories, the RICE Work Group determined that no add-on controls should be the MACT floor control type.

2.2.1.1 Control Techniques Most Likely to Reduce HAPs

The RICE Work Group reviewed control techniques used on existing RICE to identify those techniques that are most likely to reduce HAPs. Due to the lack of adequate HAP emissions data for existing engines with controls, the Work Group relied principally on engineering judgement and Work Group expertise to determine which controls would be most likely to reduce HAPs, such as formaldehyde, from existing RICE.

Most emissions control strategies for stationary RICE focus on the reduction of nitrogen oxides (NOx), either by altering the combustion process (through parametric controls or combustion modifications) or after-treatment catalytic controls. In addition, there are some after-treatment catalytic controls in place to reduce carbon monoxide (CO) and/or volatile organic compounds (VOCs). No existing control techniques are in place specifically to address the formation or reduction of HAP emissions from existing RICE.

The control techniques reviewed are presented below.

For CI liquid-fueled engines, the Work Group reviewed the following control techniques:

Oxidation catalyst
Selective catalytic reduction (SCR)
Exhaust gas recirculation (EGR)
Pre-combustion chamber (PCC)
Fuel-injection timing adjustment

NOTE: EGR and PCC are not available as retrofits for existing CI liquid-fueled RICE. Fuel-injection timing adjustment is available for only a limited number of CI liquid fuel engine models.

For CI dual fuel engines, the Work Group reviewed the following control techniques:

Oxidation catalyst
Selective catalytic reduction (SCR)
Pre-combustion chamber (PCC)

NOTE: Oxidation catalysts and SCR are not viable for CI dual fuel engines that use digester gas or landfill gas. PCC is available for only a limited number of CI dual fuel engine models.

For SI gasoline engines, the Work Group reviewed the following control techniques:

Oxidation catalyst (lean burn engines only)
Selective catalytic reduction (SCR) (lean burn engines only)
Non-selective catalytic reduction (rich burn engines only)

For SI gaseous-fueled engines, the Work Group reviewed the following control techniques:

Oxidation catalyst (lean-burn engines only)
Selective catalytic reduction (SCR) (lean-burn engines only)
Pre-combustion chamber (PCC) (lean burn engines only)
Non-selective catalytic reduction (rich burn engines only)

NOTE: Oxidation catalysts, NSCR, and SCR are not viable for SI gaseous-fueled engines that use digester gas or landfill gas. PCC is available for only a limited number of SI gaseous-fueled engine models.

The Work Group agreed that control techniques that alter the combustion process to reduce NOx emissions, including PCC and EGR, would not be likely to reduce HAP emissions, such as formaldehyde, that result from incomplete combustion. Existing combustion modification techniques reduce NOx emissions from RICE by lowering the combustion temperature in the engine cylinders. These techniques are not expected to reduce HAPs and may result in higher HAP emissions.

Based on a review of emissions test data, contacts with control equipment manufacturers and state air regulatory representatives, and the Work Group's expertise, the RICE Work Group came to consensus that add-on control devices which involve oxidation are most applicable for HAPs reduction from RICE. The primary HAPs constituent from natural gas engines is formaldehyde, CH_2O, which is formed when conditions do not allow methane to oxidize completely. Formaldehyde is a product of partial combustion, as is CO. The removal of formaldehyde and similar HAPs requires the use of a catalyst that promotes further oxidation. Three types of catalytic controls have been applied to stationary RICE for NOx reduction:

1) Selective catalytic reduction, (SCR) -- injects a "reducing agent" (typically ammonia, NH_3) into the exhaust upstream of the catalyst to "extract oxygen" from NOx compounds, transforming them into molecular nitrogen, N_2.

2) Non-selective catalytic reduction, (NSCR) -- is used on "rich-burn" engines that can operate at approximately stoichiometric (chemically correct) air-to-fuel ratios. NSCR catalysts are formulated to enhance both reduction and oxidation reactions and will lower emissions of NOx, carbon monoxide (CO), and some volatile organic compounds (VOCs). NSCR catalysts rely on the engine to produce sufficient CO to act as a reducing agent to extract oxygen from the NOx compounds. Maintaining the proper CO/NOx ratio for proper operation requires very precise air-to-fuel ratio control. NSCR may not be a viable control for digester gas or landfill gas as these fuels tend to foul the catalyst.

3) Oxidation catalysts -- are used on lean burn engines to reduce the CO and some VOCs. Oxidation catalysts may not be viable controls for digester gas or landfill gas as these fuels tend to foul the catalyst.

Current installations of SCRs are not expected to be effective in reducing HAPs, such as formaldehyde, since the SCR devices are formulated to enhance reduction reactions only. Existing SCRs do not use oxidation to lower emissions. New SCR technology has been developed that does incorporate oxidation and may be applicable for HAP reduction. However, for existing sources and for the purpose of the MACT floor, existing SCRs were not considered applicable control devices that may reduce HAPs.

NSCR catalysts are formulated to enhance both reduction and oxidation reactions.   It is therefore expected that both NSCR and oxidation catalysts will exhibit some effectiveness in oxidizing formaldehyde and other similar HAPs. Therefore, for rich burn engines, non-selective catalytic reduction (NSCR) controls are the most applicable existing control device that achieves oxidation. For lean burn engines, catalysts designed to oxidize CO are the most applicable existing control devices.

The ICCR Population Database identified “direct flame afterburners” as an emission control device for rich-burn landfill gas engines. All known stationary internal combustion engines at landfills are lean burn engines, except for 11 rich burn (stoichiometric) engines operated by a company in California. The RICE Work Group obtained more information on the type of emission control technique used on these rich-burn engines by contacting the owner/operator and by reviewing information provided by air regulatory personnel from California. Based on the information provided, the RICE Work Group determined that the control technique in place had been incorrectly classified as "direct flame afterburners" in the ICCR Population Database.

The engines in question initially were equipped with non-selective catalytic reduction (NSCR) units to control NOx emissions. After early failure of the NSCR devices, the operator met emission reduction requirements by modifying the operating parameters of the engines. These modifications included fuel-rich operation of the engines to reduce NOx formation. While successful at reducing NOx, CO emissions increased. CO was reduced by injecting air into the exhaust gas stream to oxidize the unburned fuel and “afterburn” the exhaust. Although originally considered temporary, the fuel-rich/air injection systems have been in place since the early 1980’s.

Although no actual emissions data exists, there are several theoretical problems with this emission control system. Rich-burn engines operating fuel-rich produce more CO and formaldehyde emissions than engines operating at proper air-to-fuel ratios. The injection of air must be done precisely; if either too much or too little air is injected, both the rate of exhaust gas combustion and the resulting CO reduction efficiency will be affected. Proper mixing of the injected air is also important; poor air distribution can cause sections of the exhaust gas stream to remain unburned. Even if the control system is working perfectly, there is no evidence that it will reduce HAP emissions beyond that of a properly tuned engine.

Violation notices written between January 1, 1990 and May 21, 1998, against the landfills indicate compliance problems for the control systems. At one plant, seven NOx emissions violations and two CO emissions violations were recorded. At the second plant, five NOx emissions violations and two CO emissions violations were recorded. No engine violations were recorded at the third plant.

In summary, the fuel-rich/air injection systems in use on rich-burn engines at these landfills are temporary emission control devices that are not performing consistently in the field. There is no evidence that the systems will reduce HAP emissions. On this basis, the RICE Work Group has determined that the use of fuel-rich/air injection for HAP emission control on rich-burn internal combustion engines is not appropriate.

Therefore, the RICE Work Group identified two control techniques that may reduce HAPs from existing RICE: NSCR for rich burn engines and oxidation catalysts for lean burn engines.

2.2.1.2 Prevalence of Controls Most Likely to Reduce HAPs

A breakdown, by subcategory, of emission controls for existing RICE included in the ICCR Population Database, is provided in the table below.

Based on information in the ICCR Population Database for RICE, 25% of existing engines subcategorized as Spark Ignition, Natural Gas 4-Stroke Rich Burn engines have NSCR controls installed. Therefore, the RICE Work Group determined that the average of the best performing 12 percent of existing engines for the Spark Ignition, Natural Gas 4-Stroke Rich Burn subcategory is NSCR and the MACT floor for spark ignition natural gas 4-stroke rich burn engines should be based on NSCR.

Information in the ICCR Population Database for other subcategories indicate that the average of the best performing 12 percent of existing engines in the ICCR Population Database have no controls that involve oxidation. Therefore, the RICE Work Group concluded that the MACT floor for those subcategories should be based on no add-on controls.

Emission Controls for Existing RICE Included in the ICCR Population Database

Subcategory	**No. of Units**	**No Add-on Controls (%)**	**Add-on Controls (%)**	**MACT Floor Control Type**
SI Natural Gas 4-Stroke Rich Burn	1,180	71%	25% Catalytic Reduction 4% Other	Non Selective Catalytic Reduction
SI Natural Gas 4-Stroke Lean Burn	920	94%	3% Catalytic Reduction 3% Other	No Add-on Controls
SI Natural Gas 2-Stroke Lean Burn	1,090	99%	1% Other	No Add-on Controls
SI Digester and Landfill Gas	150	89%	10% Air Injection 2% Steam or Water Injection	No Add-on Controls
SI Propane, LPG and Process Gas	150	96%	2% Miscellaneous 1% Catalytic Reduction 1% Other	No Add-on Controls
SI Gasoline	200	100%	none	No Add-on Controls
CI Liquid Fuel (diesel, residual/crude oil, kerosene/naphtha)	4,100	97%	3% Other	No Add-on Controls
CI Dual Fuel	500	95%	1% Catalytic Reduction 3% Steam or Water Injection 1% Other	No Add-on Controls
Emergency Power Units	5,700	99%	1% Other	No Add-on Controls
Small Engines (200 bhp or less)	2,900	98%	1% Catalytic Reduction 1% Other	No Add-on Controls

2.2.2 Good Combustion Practices for RICE

The RICE Work Group assessed existing good combustion practices by 1) researching and reviewing possible good combustion practices for the purpose of HAPs reduction from RICE and 2) assessing the prevalence of those practices by reviewing information available in the ICCR Population Database, information from state air permitting authorities and the expertise of Work Group members.

Based on the information presented below, the RICE Work Group concluded that no good combustion practices should be included in the MACT floor for existing RICE.

2.2.2.1 Possible Good Combustion Practices

Practices that maintain good engine performance may lead to more complete combustion, and therefore, may decrease the likelihood of increased HAP emissions that may be associated with incomplete combustion or engine failure. In general, good engine performance is sustained by proper engine operation, routine engine inspection and engine performance analyses, and, as necessary, preventive maintenance. Most existing practices have been developed as a result of economic incentives (to improve fuel efficiency and avoid costs associated with engine failure) or as a result of air emission limitations for nitrogen oxides (NOx). Descriptions of existing practices for engine operation, routine engine inspection and engine performance analyses, and preventive maintenance are provided below. The effectiveness of existing practices for fuel efficiency or NOx emission reduction is well documented. However, the RICE Work Group has not identified any data to link improved maintenance, inspection, and operating practices to reduced HAP emissions. Also, specific recommendations for maintenance and operating practices are engine-specific, site-specific, or both. Therefore, the RICE Work Group concluded that, based on a review of all available information, no specific practices are appropriate as part of the MACT floor for existing RICE.

2.2.2.1.1 Proper Engine Operation

"Operator" has been defined by the ICCR Pollution Prevention (P2) Subgroup as an individual whose work duties include the operation, evaluation, and/or adjustment of the combustion system, i.e., internal combustion engine. Both manufacturers and engine dealers conduct training schools to train dealer service personnel to assess engine operation and maintain customer engines. Engine operators are encouraged to participate in these schools.

Engine operation for stationary RICE differs depending on the type of engine, the engine's use, the size of the engine, the level of automation and age of the unit. Engine operation for CI engines is very different from engine operation requirements for SI engines. CI engines are manufactured and adjusted at the factory to produce the requisite power. Power is achieved by the proper selection of fuel system components, turbochargers, aftercooling, piston compression ratio and fuel supply. These components are, in effect, a matched set designed to achieve the desired engine performance, as well as to provide the reliability and durability demanded by the customer. This matched set of components results in an essentially adjustment-free engine that is ready to run when received by the customer. Procedures for starting and stopping the engine are covered in an Operation Manual, as are maintenance requirements (described below). A CI engine does not require an operator to evaluate and adjust the combustion system. In fact, many CI engines operate unattended and may be started and stopped by remote control. The engines are equipped with sensors to detect high coolant temperature, low oil pressure, and excessive engine speed. When these sensors are tripped, the engine load will be reduced or the engine will be shut down.

SI engines also are set in the factory, but user installations may require site-specific adjustments depending on the type of fuel used and its heating value. The increased number of engine variables associated with SI engines requires more frequent attention from an operator. Periodic checks of the oxygen content in the exhaust are required to assure continued proper engine operation. Manufacturers provide Operating Manuals that describe procedures for measuring the oxygen content of the exhaust gas and adjusting the spark timing and air-to-fuel ratio to achieve the correct oxygen levels for proper engine performance.

Many installations of RICE may not have an operator, as defined by the ICCR Pollution Prevention Subgroup. Some installations may consist of a single engine that is operated without supervision and maintained by trained service personnel from the engine dealer. For installations involving a number of engines that may operate continuously, there will be personnel in attendance to monitor the engines' operation and follow the maintenance plans developed for the specific engines and their type of operation and conditions.

The RICE Work Group determined that no operator training should be included in the MACT floor for existing RICE.

2.2.2.1.2 Routine Engine Inspection and Performance Analyses

All engine manufacturers provide their customers with recommendations about routine engine inspection and performance analyses. Some examples of engine items related to engine performance that should be inspected routinely are engine air cleaners, turbochargers, spark plugs, valve lash, ignition systems, ignition coils and wiring, and aftercooler cores. Manufacturers' recommendations for specific inspection/maintenance schedules may differ depending on the design and size of engines and whether the engine is a CI engine or an SI engine.

Some engine users develop site-specific programs of engine inspection and analyses to evaluate engine performance. These programs generally have been developed as a result of economic incentives, i.e., incentives to identify more closely when engine shutdown/maintenance is required to sustain good engine performance. Many times engine users implement these site-specific programs in lieu of the inspection/maintenance schedules recommended by the engine manufacturer. Typical engine parameters that may be inspected in these site-specific programs include temperatures, pressures, and fuel usage. Engine users rely on their extensive experience with specific engines to develop these site-specific programs and to identify when changes in the monitored parameters warrant engine shutdown for maintenance.

The RICE Work Group determined that no inspection and performance analysis requirements should be included in the MACT floor for existing RICE.

2.2.2.1.3 Preventive Maintenance

All engine manufacturers provide their customers with preventive maintenance recommendations. These recommendations specify a program of inspection and repair actions that should be conducted before a failure occurs. The objective of this repair-before-failure concept is to prevent most failures from ever occurring and to eliminate catastrophic events that could permanently disable or destroy the unit. In general these recommendations are meant to serve as a guideline to help the engine user keep the engine performing well. Also, engine owners may need to verify that preventive maintenance items have been conducted per the manufacturer's recommendations in order to maintain the warranty for the engine. Therefore, engine maintenance records are important. Accurate records can be used to determine operating costs, establish maintenance schedules, and for other business decisions. Maintenance records in some cases are required by air permitting authorities in order to document that the engine is being maintained and that any required inspections are conducted at the proper intervals.

Most engine owners implement some form of preventive maintenance program because it is a well-documented fact that preventive maintenance programs provide the best return on investment. A preventive maintenance program will ultimately reduce engine downtime because the user can plan repairs and adjust his operation schedule accordingly. This not only permits an operator to budget and control costs, but, in addition, the engine is maintained at optimum operating conditions for best performance.

Some examples of engine items related to engine performance that should be inspected, serviced, and/or replaced routinely are engine air cleaners, turbochargers, spark plugs, valve lash, ignition systems, ignition coils and wiring, and aftercooler cores. Manufacturers' recommendations for specific inspection/maintenance schedules may differ depending on the design and size of engines and whether the engine is a CI engine or an SI engine. Engine manufacturers provide Maintenance Manuals for their products that describe in considerable detail what to maintain and how to perform the maintenance. Engine owners may train on-site personnel to maintain an engine, or, in some cases, engine owners contract with the engine dealer to provide a trained serviceman to perform the recommended maintenance rather than training and having the work done by the owner's personnel.

One of the most extensive maintenance procedures for stationary RICE is engine overhaul. The overhaul period of an engine is defined as the interval after which the major wear items in the engine should be replaced. Many of the items that are replaced or rebuilt after this interval are load sensitive and total fuel consumed may be used to determine the point of overhaul rather than clock hours. Manufacturers provide information on how to adjust clock hours to account for fuel used. Therefore, hours to overhaul are application-specific and are based on a user's knowledge, experience, and records of operation.

The RICE Work Group determined that no inspection and performance analysis requirements should be included in the MACT floor for existing RICE.

2.2.2.2 Prevalence of Good Combustion Practices

The RICE WG reviewed the Population Database and the Emissions Database for inclusion of "Good Combustion Practices." In the Population Database, the data fields that were reviewed included the "Combustor Operator Training" of the "Turbine & Engine (T&E) Information" Table, and "Scheduled Shutdowns" and "Unscheduled Shutdowns" of the "Combustor Device - General" Table. No information was found in any of these data fields. Similarly, the Emissions Database did not include any references for good combustion practices for RICE. The gathered source test reports in the Emissions Database were mainly conducted for compliance purposes and did not include specific engine operating conditions, such as air-to-fuel ratio, ignition timing, and maintenance information.

For existing engines, engine manufacturers have recommended schedules to evaluate engine performance that vary by engine. In addition, users have developed inspection and maintenance schedules based on site-specific conditions or experience using an engine for a specific application.

State and local agencies known to have stringent regulations were contacted regarding "Good Combustion Practices." These agencies included California, Florida, Texas, Louisiana, North Carolina, Ventura County Air Pollution Control District, and South Coast Air Quality Management District. None of the contacted agencies, except for Ventura County APCD and Louisiana, have any requirements for good combustion practices for RICE. Instead, these agencies' requirements concentrate on emissions monitoring rather than prescribed practices for RICE.

Ventura County APCD Rule 74.9 includes a requirement for RICE operator inspection plans. The rule requires a detailed maintenance procedure and inspection schedule for each engine and emission control system. Inspections must occur either quarterly or after every 2000 hours of engine run time; compliance source testing occurs annually. Inspection logs are also required.

Certain sources in Louisiana have requirements for inspection and maintenance of RICE as a part of Title V permits. Louisiana allowed facilities to opt for the inspection and maintenance requirements in lieu of semiannual testing requirements to demonstrate compliance with emission limitations for criteria pollutants. The inspection and maintenance requirements are to be performed semiannually and include the preparation of a report with complete performance and condition analyses, adjustments made, and lists and dates for future repairs and/or maintenance work. This report must be kept on-site.

Therefore, based on a review of the available information, the RICE Work Group identified existing requirements for good combustion practices for only a few sources in two States: Louisiana and California. In both cases, the source owners and operators establish an inspection and maintenance plan that is site-specific and the content of the plan is negotiated with the air permitting authorities. The plans are in place for criteria pollutants, such as NOx. The Work Group determined that it would be inappropriate to include specific practices from those plans as a part of the MACT floor.

2.2.3 State Air Emission Regulations for HAPs

Based on a review of information available through the UATW and interviews with state air permitting authorities from Alaska, California, Louisiana, North Carolina, and Texas, the RICE Work Group was unable to identify any state air emission regulations that establish specific emission limitations for HAP emissions from RICE units.

2.2.4 State Air Permit Limitations for HAPs

No air emission limits for HAPs from RICE were identified in either the RACT/BACT/LAER databases or the UATW. Emission limits were only found for criteria pollutants such as NO_x or SO_2. Although HAP emission limits for 49 RICE were identified in the ICCR Population Database, the RICE Work Group determined that these permit limits should not be used as the basis for MACT floor since:

1. There was insufficient information in the ICCR Population Database to allow the RICE Work Group to properly subcategorize the units.
2. The HAP limits for the 49 engines are site-specific (all values are different) and it is unclear whether the limits would be achievable for engines at other facilities.
3. It is unclear whether the permit limitations are based on emissions testing or on the use of emission factors, such as AP-42.
4. The 49 engines represent less than 0.2 percent of all engines in the ICCR Population Database.

2.2.5 Emissions

The RICE Work Group reviewed the ICCR Emissions Database for RICE and associated emissions test reports to determine if the emissions data could be used for MACT floor. Based on a review of the available emissions information, the RICE Work Group determined that the existing emissions data are inadequate to identify a best performing group of existing RICE and to identify achievable emission limitations for existing RICE. The HAP emission levels reported in the ICCR Emissions Database for RICE are highly variable. For example, formaldehyde levels for natural gas-fired engines cover 6 orders of magnitude. The RICE Work Group speculated that the variability could be attributed to two possible causes:

1. reported formaldehyde levels for lean burn and diesel engines may be artificially low due to interference with DNPH-based test methods, and
2. emissions may be affected by the operating condition of the engine when tested.

The RICE Work Group carefully reviewed the test reports to determine if the variability could be explained by the operating conditions of the engines and discovered that many of the test reports lacked key information about engineering and operating parameters that could affect HAP emissions. For example, the air-to-fuel ratio often was lacking, as was the as-tested horsepower and speed. The RICE Work Group concluded that there was insufficient information in the test reports to account for the unexplained variability in the emissions data included in the ICCR Emissions Database for RICE. The Work Group also concluded that there are no existing HAPs emissions data for a single engine that was tested over its entire envelope of operating conditions. The RICE Work Group identified key emissions data gaps, including the following:

1. the effect of operating conditions on emissions, and
2. the effectiveness of possible MACT control devices in reducing HAP emissions.

EPA also has noted the deficiencies in the ICCR Emissions Database for possible MACT control devices. In an October 1, 1997 memorandum to the RICE Emissions Subgroup, EPA staff noted that although there is some data in the database for before and after controls, the data for NSCR "correspond to a limited number of pollutants and high detection limits (FTIR with a 0.5 ppm detection limit)," and the data for oxidation catalysts have the following limitations, "1) the unavailability of emission data necessary to estimate a representative control efficiency, and 2) only a small portion of the pollutants were measured before and after controls."

The RICE Work Group concluded that the available emission data are insufficient to be used as the basis for MACT floor and no HAP emission limitations or HAP emission reduction targets are included as a part of the MACT floors for existing RICE. Given the critical data gaps, the RICE Work Group agreed, by consensus, that additional emissions data are needed to support the MACT rule development. The test plan developed by the RICE Work Group and recommended to EPA by the Coordinating Committee will be conducted at Colorado State University in 1998 and will provide the Work Group with additional emissions data.